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(NASA-CE-14819C) EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS: INITIAL EVALUATION TESTS OF GINERAL ELECTRIC COMPANY 12.C AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE (Naval Weapons Support Center, G3/44)

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JUL 1976



EVALUATION PROGRAM FOR SECONDARY SPACECRAFT CELLS

INITIAL EVALUATION TESTS

OF

GENERAL ELECTRIC COMPANY

12.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS

FOR THE

INTERNATIONAL ULTRAVIOLET EXPLORER SATELLITE

PREPARED FOR GODDARD SPACE FLIGHT CENTER CONTRACT 5-53742AG



PREPARED BY

WEAPONS QUALITY ENGINEERING CENTER

NAVAL WEAPOINS SUPPORT CENTER, CRANE, INDIANA

DEPARTMENT OF THE NAVY NAVAL WEAPONS SUPPORT CENTER WEAPONS QUALITY ENGINEERING CENTER CRANE, INDIANA 47522

EVALUATION PROGRAM
FOR
SECONDARY SPACECRAFT CELLS

INITIAL EVALUATION TESTS
OF
GENERAL ELECTRIC COMPANY
12.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS
FOR THE
IMPERNATIONAL ULTRAVIOLET EXPLORER SATELLITE

WQEC/C 76-89

15 MARCH 1976

PREPARED BY

J. D. HARKNESS

PREPARED UNDER THE DIRECTION OF

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REPORT BRIEF

INITIAL EVALUATION TESTS OF GENERAL ELECTRIC COMPANY 12.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE INTERNATIONAL ULTRAVIOLET EXPLORER SATELLITE

Ref: (a) NASA Purchase Order S-53742AG

(b) Initial Evaluation Test Procedure for Nickel-Cadmium Sealed Space Cells; NADC 3053-TP324 of 10 Apr 73

I. TEST ASSIGNMENT BRIEF

- A. The purpose of this evaluation test program is to insure that all cells put into the life cycle program are of high quality by the screening of cells found to have electrolyte leakage, internal shorts, low capacity, or inability of any cell to recover its open-circuit voltage above 1.150 volts during the internal short test.
- B. The 20 cells were manufactured for the National Aeronautics and Space Administration, Goddard Space Flight Center (GSFC), under NASA contract NAS-5-19584, by General Electric Company, Gainesville, Florida, according to the Manufacturing Control Document (MCD) 232A2222AA-54. They were manufactured to GSFC's specification S-761-P-6. The cells were identified with the manufacturer's catalog number 42B012AB21-G2 with nine cells having auxiliary electrodes. The cells are from a lot of 175 cells procured for the International Ultraviolet Explorer (IUE) Project. Due to a change in requirements, the project selected to use 6.0 ampere-hour cells. Therefore, the remaining cells of this lot have been placed in storage at GSFC for use on a future GSFC project. All the cells are rated at 12.0 ampere-hours and contain double ceramic seals. Testing was funded in accordance with reference (a).
- C. Test limits specify those values in which a ceil is to be terminated from a particular charge or discharge. Requirements are referred to as normally expected values based on past performance of aerospace nickel-cadmium cells with demonstrated life characteristics. A requirement does not constitute a limit for discontinuance from test.

II. SUMMARY OF RESULTS

A. Cell, S/N 021, exceeded the pressure requirement of 65 psia during the 0° C overcharge test and cell, S/N 093, exceeded this requirement during the capacity test at 20° C. Cell, S/N 093, also exhibited higher auxiliary electrode voltages during testing as compared to the other cells.

- B. The cell containers varied in that some had convex contours whereas others had concave contours. Following test, some cells indicated an increase in the plate stack thickness, whereas, others indicated a decrease.
- C. Average ampere-hours out during the charge efficiency test at 20° C was 4.5 which was 75 percent of capacity input.
 - D. Average ampere-hours out following the overcharge at 35° C was 16.3.
- E. The average cell voltage at the end of one week open-circuit, during the charge retention test, was 1.324 volts. Average capacity output was 13.2 ampere-hours following the open-circuit stand period.
- F. The 24-hour open-circuit cell voltage following a 16-hour short period was 1.231 volts.
- G. The cells, with pressure gauges, reached a pressure of 20 psia before reaching the voltage limit of 1.550 volts during the pressure versus capacity test. The average ampere-hours in and voltage at this pressure were 18.5 ah and 1.506 volts respectively. Ten cells exhibited pressure decay in the range of 1 to 4 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 15.0 ampere-hours.

III. RECOMMENDATIONS

- A. Manufacturing processes and controls should be such to prevent swelling of the plate stack, thereby preventing cell case distortion.
- B. It was recommended that these cells be placed on life test under various orbit regimes simulating various spacecraft load requirements.
- C. In March 1976, three packs (8F--1.5 hour orbit, 20° C; 8G--1.5 hour orbit, 0° C; 8H--24 hour orbit, 20° C) and in April pack 228A--synchronous orbit, 20° C, will begin test.

RESULTS OF INITIAL EVALUATION TESTS OF

GENERAL ELECTRIC COMPANY 12.0 AMPERE-HOUR NICKEL-CADMIUM SPACECRAFT CELLS FOR THE INTERNATIONAL ULTRAVIOLET EXPLORER SATELLITE

I. TEST CONDITIONS AND PROCEDURE

- A. All evaluation tests were performed at room ambient (RA) pressure and temperature ($25^{\circ} \pm 2^{\circ}$ C), with discharges at the 2-hour rate, and in accordance with reference (b), unless otherwise specified, and consisted of the following:
 - 1. Phenolphthalein leak tests (2).
- 2. Three capacity tests, third at 20° C, with internal resistance measurements during second charge/discharge.
 - 3. Auxiliary electrode characterization test.
 - 4. Charge retention test, 20° C.
 - 5. Internal short test.
 - 6. Charge efficiency test, 20° C.
 - 7. Overcharge tests; 0° and 35° C.
 - 8. Pressure versus capacity test.
 - 9. Phenolphthalein leak test.

(See Appendix I for summary of test procedure.)

II. CELL IDENTIFICATION

A. Eleven cells were manufactured without auxiliary electrodes while the other nine cells have auxiliary electrodes. The cells were identified by the manufacturer's catalog number 42B012AB21-G2, with serial numbers 01640208- (021 to 172, noninclusive) -L03. Fourteen cells were fitted with pressure gauge assemblies and all the cells were placed in temporary pack configurations for initial testing.

B. The 12.0 ampere-hour cell is rectangular with average physical dimensions as follows:

		!_ength	(In)	
Overali Height (In)	Edge Maximum	Center Pre- Test Maximum	Center Post- Test Maximum	Width (In)
4.564	.879	.886	.889	2.982

- C. The cell containers and covers are made of stainless steel. The positive and negative terminals are insulated from the cell cover by ceramic seals and protrude through the cover as solder-type terminals.
- D. The production of the cells for the I.U.E. Program represents the second generation of cells manufactured with the specific objective of reducing the active material loading. As a result, several key cell design parameters were incorporated into the production. Details of cell design, construction, manufacturing and performance during acceptance testing by the manufacturer are summarized and reported in GSFC Report X-711-16-18 of January 1976.
- III. RESULTS--The following was condensed from Tables I through VII.
- A. Cell, S/N 021, exceeded the pressure requirement of 65 psia during the 0° C overcharge test and cell, S/N 093, exceeded this requirement during the capacity test at 20° C. Cell, S/N 093, also exhibited higher auxiliary electrode voltages during testing as compared to the other cells.
- B. The cell containers varied in that some had convex contours whereas others had concave contours. Following test, some cells indicated an increase in the plate stack thickness, whereas, others indicated a decrease.
- C. Following is a listing of the average end-of-charge (EOC) voltages and capacity output in ampere-hours (ah):

Charge	Volts	ah Out
c/20 for 48 hours at 29	5° C 1.436	15.7
c/10 for 24 hours at 29		14.9
c/10 for 24 hours at 20		14.4
c/10 for 24 hours at 20	o° C* 1.450	13.2
c/40 for 20 hours at 20	0° C** 1.369	4.5
c/20 for 60 hours at 0°	° C 1.485	15.0
c/10 for 24 hours at 39	5° C 1.401	16.3

^{*} Charge retention test.

^{**} Charge efficiency test, 6 ah input.

D. Average internal resistance measurements (milliohms):

Measurement Taken	Resistance
30 Min before end of charge (cycle 1)	2.70
1 Hr after start of discharge (cycle 2)	2.68
2 drs after start of discharge (cycle 2)	2.52

- E. The auxiliary electrode characteristic test was performed in which maximum signal power was obtained with a 200-ohm resistance; but a 300-ohm resistance was used throughout the tests as instructed by Goddard Space Flight Center's Technical Officer.
- F. The average cell voltage at the end of 1 week open-circuit, during the charge retention test, was 1.324 volts.
- G. The 24-hour open-circuit average cell voltage following a 16-hour short period was 1.231 volts.
- H. The 14 cells, with pressure gauges, reached a pressure of 20 psia before reaching the voltage limit of 1.550 volts during the pressure versus capacity test. The average ampere-hours in and voltages at this pressure were 18.5 ah and 1.506 volts respectively. The cells exhibited pressure decay in the range of 1 to 4 psia during the last 30 minutes of the 1-hour open-circuit stand. Average capacity out was 15.0 ampere-hours.

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		Other											ESKS													÷			
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2	POST	Terminals	+											-					-										_
K TEST	-	the the										-	ERKS				-				-					-			<u> </u>
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E		Other										_	LEAKS	_												_			
	INITIA	erminals	•										3	- -															L
		Ten	+																										
	WIOTH	Inches)		2.978	2.987	2,986	2.580	2.979	2.983	2.984	2.588	2.985	2.977	2.930	2.980	ુક <i>ક</i> ા	2,983	2882	2.977	2,979	2.990	2.978	2.581						
		HAXIMUM	POST-TEST	.870	.890	.880	.890	.950	,883	.887	.895	,895	.895	885	888.	. 890	.886	678.	.885	ं ४४०	.885	1877	.886						
	LENGTH (Inches)		MAKIMUM	.880	.885	.875	.877	878.	.873	ን 88.	718.	568.	.885	.875	0€8.	.877	.877	288.	318.	818	688,	.880	.881						
	LEX	MAX I MUM	(PRE-TEST	.893	.800	.873	.892	.900	.885	.894	218.	978.	768	≥88	ુ 86	. 895	€88,	. 38 5	.883	.893	}88d.	2008.	168.						
	HEIGHT	$\overline{}$		4.568	4.556	4.562	4,560	4.556	4.567	4.568	4,565	4.565	4.580	4.567	4.568	4.56c	4.556	4.550	4.561	4.530	4.565	4.568	4.564						
	WEIGHT	(Grams)		869.3	544.3	905.1	5.43.8	549.0	547.6	546.5	766.0	936.0	769.2	934.1	504.4	2.88.8	887.5	82.5	8.508	913.9	761.5	931.9	869.0						
	SERIAL	NUMBER		120	030	950	045	083	380	089	0%0	160.	093	760	096	099	ر ۲۶	(5.	152	158	157	(63	172						

TABLE II

44	END	Capacity Jest 1	30				Capacity	v Test 2	-			300	Capacity lest 3 (20°C)	lest 3	(20°C)	100	-	-
48	E	DE-CHAP	30	A				C. L.	-			320		777	200	111111111111111111111111111111111111111		
48	-		3	ERD-	OF-DISCHA	N.K.G.E.	ENC	ACT-CIAR	4	END-OF-	ST-DISSERRE	KIE.	1111	5	N. J.C.	T. I.	OF-UL JUHEGE	APGE
	(volts)	ELECT (Volts)	PRESS (PSIA)	CAPAC- 1 TY (ah)	CAPAC- AUX ITY ELECT PRI (ah) (Volts) (PS	PRESS (PSIA)	CELL (Volts)	AUX LECT olts)	PPESS (PSIA)	CAPAC- (ITY (ah)	FLECT (Yolts)	PESS (PSIA)	CELL (Volts)	ELECT (Volts)	PRESS (PSIA)	CAPAC BATTE	ELECT (Volts)	PRESS (PSIA)
	1.434		19	1.9/		7	1.441		28	15.5		9	1.456		58	14.1		+1
	1.432			15.8			1.439			14.8			1.451			13.9		
++	1.433		20	1.91		9	1.460		62	15.3		0/	1.453		52	14.1		1
-	1.433			16.2			1.439			15.2			1.452			14.1		
580	1.436	.385		15.8	510.		1.442	r497		14.9	010.		1.458	685.		14.0	4.4	
	1.435	119.	9	15.8	120.	6	1.440	709.	47	14.5	510.	81	1.454	SIL.	69	14.1	A. S.	25
1 680	1.436	407	,	12'51	781.		1.442	.519		14.6	.0/3		h5h'1	. 530		14.2	N.A.	
-	1.438	413	29	15.2	122,	9/	1.443	,533	17	14.5	N.A.	7	1.456	195'	35	14.1	A.5	7
	1.442	317.	6/	12:1	110.	9	1.446	,555	33	14.2	ros.	12	1.455	,536	33	14.6	250.	7
	1.436	.349		15.8	700.		1.441	.509		15,2	.013	17	1.453	,538		14.5	A.A	
	1.443	.509	11	15.2	810.	٨	1.444	.553	77	14.3	31.	3	1.453	Ihs.	22	(4.7	026	6
	1.438	tot.		8:5/	400.		1.444	954.	•	14.9	.019		1.461	415		14.4	N. A.	
	-	.468	13	15.8	210.	3	1.442	.549	25	14.7	P10.	7	1.458	548	30	14.1	N. A.	7
	-		81	15.6		7	1.444		29	15.4		3	1.451	7	44	15.6		0)
-	1.435		20	15.6		6	1.443		31	15.3		6	1.450		و	15.5		21
	1.430		13	15.5		5	1.446		2.1	15,2		2	1.451		972	15.3		7
	1.435		18	15.8		9	1,443		33	14.7		01	1.459		46	14.3		12
	1.435		16	15.8		ن	1.448		27	14.8		1	1.453		15	14.1		=
-	1.432		17	15.7		7	1.438		31	14.8		7	1.451		70	14.2	4	Ī
	1.437		#/	15.8		9	1.443		77	14.6		9	1.454		43	14.3		0
AA	not avail	48/6																
																		1
														7	-			1
9MD-NADC (SP 11/73)	P 11/7	1		ORIGI	ORIGINAL: D.	1						-			-	-		

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TABLE III INTERNAL RESISTANCE AND SHORT TEST DATA

9ND-NADC (SP 11/73)

	19	ITERNAL RESISTANCE (M	ILLIOHMS)	INTERN	AL SHORT	TEST
SERIAL NUMBER	END-OF-CHARGE	ONE HOUR AFTER START-OF-DISCHARGE	TWO HOURS AFTER START-OF-DISCHARGE	AFTER 16 HR SHORT	AFTER 2 OCV S	
		START-91-DISCHARGE	START-OF-DISCHARGE	CELL	CELL	PRESS
021	3.0	3.1	2.8	.044	1.229	5
030	2.6	2.3	2.2	.04)	1.231	
038	2.8	3.0	2.6	,043	1.228	10
045	3.2	3.0	3.0	.048	1.235	
083	2.8	3.0	2.8	,047	1.238	
093	2.9	2.9	2.8	.047	1.238	14
089	2.6	7.6	2.4	.047	1.236	
090	3.1	3.0	2.4	.050	1.238	2
091	2.9	2.1	2.5	.060	1.222	4
088	2,2	2.5	2.4	.046	1.235	
094	2.4	2.6	2.5	.059	1.220	3
096	3.1	3.0	2.4	,050	1.242	
099	2.8	2.9	2.6	.050	1.241	5
147	2.3	2.5	2.2	,023	1.213	2
151	2.1	2.2	2.4	.027	1.216	4
152	2.2	2,1	2,2	.020	1.216	2.
158	2.6	2.8	2.3	.049	1.242	5
159	2.6	2.5	2.6	.046	1,236	0
163	3.4	3.1	2.9	.047	1.234	5
172	2.3	2.3	2.3	.047	1.238	5.

TABLE IV CHARGE RETENTION TEST DATA

	END-	OF-CHAR	IGE	24	HR. 00	٧	1 %	EEK OC	1	END-0	F-DISCI	ARGE
SERIAL NUMBER	CELL (VOLTS)	AUX. ELECT. (VOLTS)	PRESS (PSIA)	CELL (VOLTS	AUX. ELECT. (VOLTS	PRESS. (PSIA)	CELL (VOLTS)	AUX. ELECT (VOLTS	PRESS. (PSIA)	CAPAC- ITY (AH)	AUX. ELECT. (VOLTS)	
021	1.454		55	1.363		6	1.52.5		5	13.8		5
030	1.450			1.364			1.323			13.1		
038	1.481		50	1.364		11	1.325		9	13.7		9
045	1.449			1.363			1.325			13.4		
083	1.455	.526		1.364	N.A.		1.324	.003		13.0	,010	
093	1.451	.709	63	1.362	N.A.	17	1.323	N.A.	16	12.8	.015	15
089	1.451	,508	٠	1.364	N.A.		1.325	N,A.		12.9	.010	
090	1.454	.541	30	/.363	N.A.	3	1.324	N.A.	2	127	310.	2
691	1.448	.552	35	1.359	.047	6	1.324	,003	5	13.2	.008	5
088	1.451	,508		1.363	N.A.		1.325	N.A.		/3.3	.013	
094	1.446	.542	23	1.360	.041	5	1.324	.003	5	13.3	.013	5
096	1.457	.497		1.364	N.A.		1.326	,003		13.0	,008	
099	1.453	.537	25	1.363	N.A	7	1.325	.00	5	13.0	.040	4
147	1.444		41	1.362		5	1.325		3	14.2		3
151	1.443		43	1.362		5	1.326		2	14.1		5
152	1.445		23	1,362		5	1.320		2	13.8		4
158	1.456		40	1.363		9	1.327		6	13.0		6
157	1.451		47	1.362		1	1.325		0	12.9		٥
163	1,449		60	1.363		10	1.325		5	13.0		5
172	1.451		35	1.362		6	1.325		6	12.6		6
N.4	Not	Avoilal	le									
						·		i	<u>+</u>			

	- 1
	ge Data
Value 14 10 1	Overcharge
LE	and (
TABLE	Efficiency
	Charge

CELL ELECT PRESS TYC ELECT PRESS CELL ELECT PRESS TYC ELECT TYC	Second Color Color	CAPPIC PRESS THE FILET PRESS THE PRESS THE PRESS THE T
Secondary Capacida Capacida	Secondary Control Co	CELL FLECT PRESS CAPACL CAPAC
15.2 15.4 29 14055 15 14.05 15.1 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 14.05 15.2 15.	15.2 15.4 29 1405 15 16.0 16.9 16.0 16.9 16.0 16.9 16.0	1385 15.4 29 1405 15 16.9 16.9 15.1 15.2 1399 10 16.9 16.5 12.8 15.4 14.5 1399 1395 16.6 12.8 13.4 15.1 14.6 13.8 13.9 16.6 12.8 13.9 15.1 14.6 13.9 14.5 15.1 14.6 13.9 14.5 15.1 15.1 14.6 13.9 14.5 15.1
19 15.2 1.598 10 16.0 1.598 10 16.0 16.0 15.1 1.598 10 16.0 1.598 10 16.0 1.598 1.	19 15.4 9 1.398 10 16.6 1.898 1.0 16.6 1.898 1.0 16.6 1.898 1.0 16.6 1.898 1.0 16.6 1.898 1.0 16.6 1.898 1.0 16.6 1.898 1.34 1.0 1	19 15.2 1.398 10 16.0 1.385 1.0 16.0 1.00 1.385 1.00 1.
19 15.4 19 1.398 10 16.9 1.885 1.585 1.665 1.285 1.489 1.386 1.386 1.285 1.489 1.386 1.285 1.489 1.386 1.285	19 15.4 19.1 14.01 15.5 16.5 17.8 17.5 1	19 15.4 9 1.398 10 16.5 15.4 10.4 136 136 136 16.5 1489 14 15.1 10.4 13.94 1389 138 13.4 15.1 10.4 13.9 1389 13.4 15.2 10.4 10.5 13.9 13.9 15.3 15.4 10.6 15 14.6 10 15.6 10.5 15.4 15.1 10.4 10.5 13.8 10.5 15.5 10.5 10.5 10.5 10.5 15.6 10.7 10.5 10.5 15.7 10.6 9 11.4 10 15.6 15.8 13.4 10.6 10 15.6 10.5 15.8 13.4 10.6 10 10.5 15.8 13.4 10.6 10 10.5 15.8 13.4 10.6 10 10.5 15.8 13.4 10.6 10 10.5 15.8 13.4 10.6 10 10.5 15.8 10.5
1885 15.4 1401 369 16.5 128 1489 14 15.2 12.4 128 1396 15.2 128 1396 15.2 128 1396 15.2 1296 128 1296 128 1296 128 1296 128 1296 128 1296	1885 1554 1401 1369 1665 128 1489 1491 1364 1364 1369 1465 128 1489 1491 1364 1369 1389 13	1.401 1.40
1487 14 15.1 1481 1364 1545 1546 1547 1518 1396 1349 1346 1349 1346 1349 13	1487 14 15.1 1481 1364 15.4 1481 1364 13	1885 15th 1401 1364 1465 128 1489 14 15th 1376 1376 1377 15 15 15 15 15 15 15
184 14 15.1 11.04 1.346 1.347 21 16.6 1.28 1.361 1.348 1.345	14 15.1 13 1.396 .547 21 16.6 128 13.6 13.6 13.8 13.6 13.8 13.6 13.8 13.6 13.8 13.8 13.4 10.10 15 14.6 13.8 13.8 13.4 10.10 15 14.6 13.8 13.8 13.4 10.10 15.6 13.8 13.8 13.4 10.10 13.6 13.8	148
1,50 15.1 1,14 1,398 395 16.6 1,509 1	1,50	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1,
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345 38 13.4 .010 15 11403 .386 12 156 .057 345	345 38 38 134 .010 15 1.463 386 12 156 .000 345 22 15.2 1146 1.001 .381 1.056 .000 374 22 15.4 1146 1400 .434 20 15.8 .000 374 22 15.4 1146 11 1400 .434 20 15.8 .000 375 14.3 22 1.403 13 12 16.0 375 15.4 11.4 11.406 33 13 16.0 375 15.4 11.4 11.406 33 15.5 375 15.4 11.4 11.406 33 15.5 375 15.7 11.406 21 16.6 375 15.7 11.406 21 16.0 375 15.7 11.406 21 15.5 375 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.5 375 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.7 15.5 375 15.7 15.7 15.7 15.7 15.7 15.7 15.7 15	345 38 13.4 .010 15 1.405 .386 12 15.6 .070 345
.345	.345	.436 22 13.5 .006 9 1.401 .426 10 15.6 .088 .334 22 13.5 .006 9 1.401 .426 10 15.6 .088 .444 22 15.4 .0.4 11 1.400 .434 20 15.6 .030 45 14.3 22 1.403 13 15.1 45 14.3 22 1.403 13 16.1 46 15.4 .0.4 47 1.406 39 15.5 47 15.2 .0.4 39 1.396 21 16.4 48 15.2 .0.4 33 1.396 21 16.5 55 15.1 .0.4 33 1.396 25 16.5
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45 15.4 11 1,400 ,434 20 15.8 ,070 ,444 21 15 1403 ,434 20 15.9 ,070 ,434 21 14.8	444 22 15.4 11 1.400 .434 20 15.8 .070 45 14.3 22 1.403 13 16.1 30 13.9 11 1.404 14 16.0 40 15.4 11.404 14 16.0 48 15.2 11.40 28 1.396 21 16.4 55 15.1 11.40 433 1.396 21 16.5 55 15.1 11.40 433 1.396 22 16.5	45 15.4 11 1,400 .434 20 15.8 .070 45 14.3 22 1,403 13 16.1 30 13.9 11 1,404 14 16.0 48 15.2 14.8 35 1,396 21 16.5 55 15.2 14.8 35 1,396 22 16.5
51 14,6 23 1,403 15 15,9 15,10 14,00 14,00 13,9 15,10 14,00 14 16,10 14,00 14 16,10	30 13.9 1.403 15.9 15.9 45 1403 15.9 1403 15.9 15.9 14.3 16.1 14.04 14.0 15.4 10.04 14.06 39 15.5 16.5 15.9 15.2 10.8 15.9 15.2 10.8 15.9 15.2 10.8 15.9 15.2 10.5 10.5 10.5 10.5 10.5 10.5 10.5 10.5	51 14,6 23 1,403 15 15,9 15,10 14,3 13,10 14 16,10 14 16,10 14 16,10 14 16,10 15,1
45 14.3 22 1,403 13 16.1 30 13.9 11 1,404 14 16.0 40 15.4 N.A 47 1,406 39 15.5 48 15.2 N.A. 33 1,396 21 16.4 29 15.1 N.A 28 1,396 25 16.5	45 14.3 22 1,403 13 16.1 30 13.9 11 1,404 14 16.0 40 15.4 10.4 47 1,406 39 15.5 48 15.2 10.4 35 1,396 21 16.5 29 15.1 10.4 28 1,399 25 16.5	45 14.3 22 1,403 13 16.1 30 13.9 11 1,404 14 16.0 40 15.4 N.A 47 1,406 39 15.5 48 15.2 N.A 33 1,396 21 16.4 29 15.2 N.A 28 1,396 25 16.5
30 139 11 1.404 14 16.0 40 15.2 N.A. 47 1.406 39 15.5 48 15.2 N.A. 33 1.396 21 16.4 55 15.2 N.A. 33 1.396 22 16.5 29 15.2 N.A. 38 1.399 25 16.5	30 139 11 1.404 14 16.0 40 15.4 10.4 47 1.406 39 15.5 48 15.2 10.4 38 1.396 21 16.4 55 15.2 10.4 38 1.396 22 16.5 29 15.2 10.5	30 139 11 1,404 14 16.0 40 15.2 N.A. 47 1,406 39 15.5 48 15.2 N.A. 33 1,396 21 16.5 29 15.2 N.A. 33 1,396 22 16.5
40 (5.4 N.A 47 1.406 39 15.5 48 15.2 N.A 33 1.396 22 16.5 55 15.2 N.A 33 1.396 22 16.5	40 (5.4 N.A 47 1.406 39 15.5 40 15.2 N.A. 33 1.396 22 16.5 29 15.2 N.A 28 1.399 25 16.5	40 (54 N.A 47 1.406 39 155 40 15.2 N.A 33 1.396 22 16.5 29 15.2 N.A 28 1.399 25 16.5
48 15.2 N.A. 28 1,396 21 16.4 55 15.2 N.A 33 1,396 22 16.5 29 15.2 N.A 28 1,397 25 16.5	48 15.2 11.A. 28 1396 21 16.4 55 15.2 11.A 33 1.396 22 16.5 29 15.2 10.4 28 1.399 25 16.5	48 15.2 N.A. 28 1,396 21 16.4 55 15.2 N.A 28 1,397 25 16.5
25 15.2 N.A 33 1.396 22 16.5 29 15.2 N.A 28 1.399	25 15.2 N.A 28 1.396 22 16.5	25 15.2 N.A 23 1.396 22 16.5 29 15.2 N.A 28 1.399
1 15.7 N.A 28 1.395 25 16.5	29 15.1 N.A 28 1.395 25 16.5	19 15.7 N.A 28 11.395 25 16.5

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TABLE VI PRESSURE VS. CAPACITY TEST DATA

					PRE	PRESSURE VS.	. CAFACITY	TEST	DATA						
Serial No.	120	038	093	990	160	\$60	940	147	121	1251	158	129	/63	111	
Start-of-Charge, Press.	<i>h</i>	7	8	10	5	5	4	>	4	5	5	Ð	3	7	
AH in to 5 PSIA	5.0	6.0	2/4	<i>∾/\</i>	a ,	2/4	1/4	67%	h.p.	~/a	2/10	15.0	14.0	W/W	
Cell (wolts)	9047	1.407						1.434	1.410			1.450	7:436		
Aux (volts)															
AH in to 10 PSIA	17.71	18.1	15.4	a/ ∼	17.0	12.5	5.0	17.8	7.6	17.5	17.0	17.5	0,7,	14.5	
Cell (voits)	1.474	1.504	1,443		1.470	1.487	1.406	1.487	1478	1.42	1.485	1.488	1.485	1.446	
Aux (volts)			.361		162,	175.	010.								
AH in to 15 PSIA	18.1	18.7	2.61	16.5	17.9	18.2	17.8	18.5	18.3	/8.3	17.8	17.9	17.9	17,5	
Cell (volts)	1.506	1.516	1.503	195%	1.503	1.505	1.516	1.503	8677	5637	715"	767.1	1.504	1.494	
Aux (volts)			.565	.316	.366	SC#'	.359								
AH in to 20 PSIA	18.7	19.5	18.0	17.3	18.4	18.7	18.3	8.8/	18.7	8.8/	18.0	18.4	18.3	18.4	
Cell (volts)	h15:1	1.51	12151	1.490	1.505	1.503	1.520	7.505	1434	1.499	1.512	525"	1,502	1.507	
Aux (volts)			८ 58 7	.387	Czp.	625.	. ۴۶۶								
AH In to V/L (1.55V)													i		
Aux (volts)															•
Press (PSIA)															
30 Min OCV, Cell	1.405	1.408	1.401	1.341	1.893	1,393	1.405	1.394	1.394	1.395	1.401	1.401	1.401	1.401	
Aux (volts)			.553	.309	.458	.488	8>>								
Press (PSIA)	77	61	20	16	17	27	72	23	20	97	92	12	25	77	
1 hour OCV. Cell	1.399	1.401	1.397	1.388	1.387	1.387	1399	1.387	4388	1.389	1.396	1.96	1.396	1.3%	
Aux (volts)			.533	127	,42J	.413	.432								
Press (PSIA)	20	17	18	15	6/	17	જ	92	18	"	8/	19	7.7	81	WQE
EOD AH OUT	151	15.8	14.6	14.1	15.5	15.6	14.4	15.9	15.8	8:5/	14.6	14.4	14.4	142	7
Aux (volts)			31)	132	660.	080'	321.								<u>-i</u>
Press (PCIA)	%	و	6	7/	7	9	0)	7	%	7	7	4	9	3	Ï
N/A - Not applicable	6 1€														

9ED-KADC (SP 11/73)

WQEC/C 76-89

SPECIAL RESISTANCE CHARACTERISTIC DATA THE AUXILIARY ELECTRODES

		-	-	-	-					-			131	-	- 1		7
AGE *	MILLIWATTS	.07	5),	,24	.3%	. 51	. 33.	29.	85.	9,46	.34	. 13	1.	80.	So'	þ¢.	40.
AVERAGE	VOLTS	.836	.793	25.	.603	.503	.360	. 249	، ۱ده	960.	3.50.	₩60.	310.	600.	500'	500'	700'
1	PRESS																
	VOLTS																
	PRESS	51	ری	51	15	15	14	ימ	7	14	1,4	7.	*/	+1	14	14	11
44	VOLTS	178.	.795	169.	.610	125.	.400	ın.	161.	811.	200.	2)40.	17.0'	.012	100.	8.	200.
	PRESS	15	15	15	15	151	15	15	15	(5	151	15	15	15	15	15	15
76	VOLTS	578.	.809	,695	109'	11S'	.387	992.	201'	850.	950'	.033	710.	800.	200'	.003	100'
93 94 99	PRESS	31	31	31	31	3(31	31	31	31	3/	31	31	3/	31	31	31
93	VOLTS	8.8	858'	. 798	.735	799.	.555	79h.	ph2.	hoz.	82.	.077	.036	020.	710'	500'	700,
,	PRESS	ıS	15	1/2	15	15	15	15	15	15	15	15	15	15	15	15	51
16	VOLTS	128.	צנני	.688	365'	.469	762.	361.	./30	.073	יסילנ	510	010,	900.	.003	200.	100.
SERIAL 40.	OHMS	000,01	5,000	2,000	1,000	200	200	100	20	20	10	2	2	-	0.5	0.2	0.1

Note: All pressures in PSIA.

POWER = $\frac{V^2}{R}$ Watts 10³ Milliwatts . Milliwatts * Excluding Cell 4/4 93 because High Preserve during test

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APPENDIX I

I. TEST PROCEDURE

A. Phenolphthalein Leak Tests:

- 1. This test is a determination of the condition of the welds and ceramic seals on receipt of the cell and following the last discharge of the cells (Cycle #8).
- 2. The cells were initially checked with a one-half of one percent phenolphthalein solution applied with a cotton swab and then placed in a vacuum chamber and exposed to a vacuum of 40 microns of mercury or less for 24 hours. Upon removal they were rechecked for leaks and then received a final check following test completion. The requirement is no red or pink discoloration which indicates a leak.

B. Capacity Tests:

- 1. The capacity test is a determination of the cells' capacity at the c/2 discharge rate to 0.75 volt per cell, where c is the manufacturer's rated capacity. This type discharge follows all charges of this evaluation test.
 - 2. The charges for the capacity tests are as follows:
- a. c/20, 48 hours, room ambient (RA), cycle 0, with a test limit of 1.52 volts or pressure of 100 psia;
- b. c/10, 24 hours, RA, cycle 1, with a test limit of 1.52 volts or 100 psia pressure and a requirement of maximum voltage (1.48) or pressure (65 psia);
- c. c/10, 24 hours, 20° C, cycle 2, with the same limits and requirements as the charge of cycle 1.
- C. Special Resistance Characterization Tests for Auxiliary Electrode Cells:
- 1. The purpose of this test is to determine the resistance to be placed across the cell's auxiliary electrode and negative terminals which will provide maximum signal when the cell is fully charged.
- 2. The cells are charged at c/10 for 24 hours at the room ambient temperature following their initial charge/discharge cycle. Following this the cells are continued on charge with the current reduced, if necessary, to maintain the real's voltage below 1.520 volts and to stabilize the pressure between 10-2 ceia. Resistance values, between 10,000 ohms and 0.1

ohm are then placed between the auxiliary electrode and the negative terminal. The cells are allowed a minimum of 5 minutes, at each resistance value, to obtain an equilibrium voltage across this resistance. This voltage value is then recorded and by calculation using the equation $P = E^2/R$ the resistance that produces maximum power is determined.

D. Internal Resistance:

1. Measurements are taken across the cell terminals 0.5 hour before the end-of-charge (EOC) on cycle 1; and 1 and 2 hours after the start-of-discharge of cycle 2. These measurements were made with a Hewlett-Packard milliohmmeter (Model 4328A).

E. Special Charge Retention Test, 20° C:

- 1. This test is to establish the capacity retention of each cell following a 7-day open-circuit stand in a charge mode.
- 2. The cells are charged at c/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure. They then stand on open-circuit for 7 days, with the requirement that the open-circuit voltage of each cell, following this period, is within \pm 5 millivolts of the average cell voltage. The cells are then discharged and 80 percent capacity out of that obtained in cycle 3 is required.

F. Internal Short Test:

- 1. This test is a means of detecting slight shorting conditions which may exist because of imperfections in the insulating materials, or damage to element in handling or assembly.
- 2. Following completion of the third capacity discharge, the cells are shunted with a 0.5-ohm, 3-watt resistor for 16 hours. At the end of 16 hours the resistors are removed and the cells stand on open-circuit voltage (OCV) for 24 hours. A minimum voltage of 1.15 is required at the end of 24 hours.

G. Charge Efficiency Test, 20° C:

- 1. This test is a measurement of the cells' charge efficiency when charged at a low current rate.
- 2. The cells are charged at c/40 for 20 hours with a test limit of 1.52 volts or 100 psia pressure. They are then discharged and the requirement is that the minimum capacity out equals 55 percent of capacity in during the preceding charge.

H. Overcharge Test #1, 0° C:

- 1. The purpose of this test is to determine the degree to which the cells will maintain a balanced voltage, and to determine the cells' capability to be overcharged without overcharging the negative electrode.
- 2. The cells are charged at c/20 for 60 hours. The test limits are cell voltages of 1.56 or greater for a continuous time period of 2 hours or pressures of 100 psia. The requirement is a voltage of 1.520 or a pressure of 65 psia. The cells are then discharged and 85 percent capacity out of that obtained in cycle 3 is required.

I. Overcharge Test #2, 35° C:

- 1. This test is a measurement of the cells' capacity at a higher temperature when compared to its capacity at 20° C. This test also determines the cells' capability of reaching a point of pressure equilibrium; oxygen recombination at the negative plate at the same rate it is being generated at the positive plate.
- 2. The cells are charged at c/10 for 24 hours with a test limit of 1.52 volts or 100 psia pressure and a requirement of 1.45 volts or 65 psia pressure. The cells are then discharged with a requirement that capacity out equals 55 percent capacity out as obtained in cycle 3.

J. Pressure Versus Capacity Test:

- 1. The purpose of this test is to determine the capacity to a pressure and the pressure decay during charge and open-circuit stand respectively.
- 2. Each cell is charged at c/2 to either a pressure of 20 psia or a voltage of 1.550. Recordings are taken on each cell when it reaches 5, 10, 15 and 20 psia pressure. The cells then stand OCV for 1 hour with 30-minute recordings and then are discharged, shorted out and leak tested.